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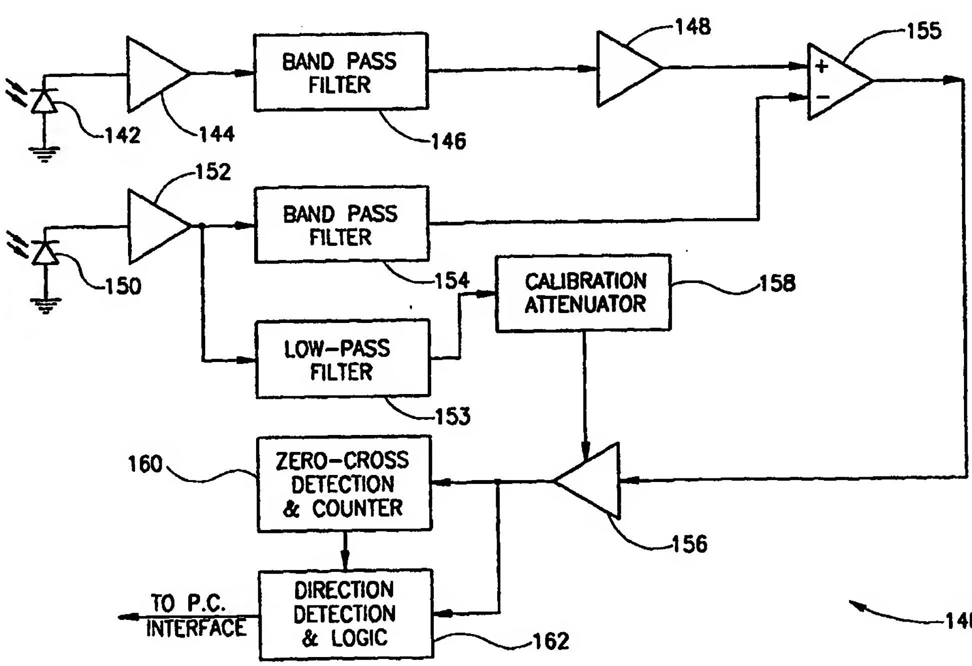

(57) Abstract

A method for determining the relative motion of a surface with respect to a measurement device comprising: illuminating the surface with incident illumination; detecting illumination reflected from the surface to form at least one detected signal; and determining the amount of relative motion parallel to the surface from said at least one detected signal, characterized in that said determining includes correcting for the effects of relative motion perpendicular to the surface.

AMENDED CLAIMS

[received by the International Bureau on 19 September 1999 (19.09.99);
original claims 1-173 replaced by new claims 1-183 (25 pages)]

1. A method for determining the relative motion of a surface with respect to a measurement device comprising:

illuminating the surface with incident illumination;

detecting illumination reflected from the surface to form at least one detected signal;

determining the amount of relative motion parallel to the surface from said at least one detected signal; and

correcting the determination of relative motion parallel to the surface for the effects of relative motion perpendicular to the surface utilizing signals derived from the same incident illumination used to determine the amount of relative parallel motion.

2. A method according to claim 1 wherein said at least one signal comprises at least two signals, at least one first signal which is affected by relative motion parallel to the surface and relative motion perpendicular to the surface and at least one second signal which is affected at least by motion perpendicular to the surface, and

wherein determining comprises determining the amount of relative motion parallel to the surface from the two signals.

3. A method according to claim 2 wherein determining comprises:

determining a first amount of relative motion from at least one of said two signals, said first amount of relative motion including a component parallel to the surface and a component perpendicular to the surface;

determining a second amount of relative motion from at least one of said two signals, said second amount of relative motion including a component perpendicular to the surface; and

determining the amount of relative motion parallel to the surface responsive to the first and second determined amounts of relative motion.

4. A method according to claim 3 wherein the second amount of relative motion does not include a component parallel to the surface.

5. A method according to claim 3 wherein the second amount of relative motion includes a component parallel to the surface.

6. A method according to any of the preceding claims wherein relative motion perpendicular to the surface is determined based on a Doppler shift of the reflected illumination.

7. A method according to claim 2 wherein determining comprises determining the amount of relative motion parallel to the surface directly from the two signals without determining the amount of relative motion perpendicular to the surface.

8. A method according to claim 7 wherein said at least one second signal is substantially determined by relative motion perpendicular to the surface.

9. A method according to claim 7 wherein said at least one second signal is a signal based on a Doppler shift.

10. A method according to claim 7 wherein said at least one second signal is responsive to relative motion parallel to the surface.

11. A method according to any of the preceding claims and including determining the amount of relative motion perpendicular to the surface.

12. A method according to any of the preceding claims wherein determining the amount of relative motion parallel to the surface includes determining the amount of relative motion along two non-colinear directions.

13. A method according to any of the preceding claims wherein the illumination is perpendicularly incident on the surface.

14. A method according to any of the preceding claims wherein detecting comprises coherently detecting.

15. A method according to claim 14 and including:

reflecting or diffracting a portion of the illumination from an object, which is part of the measurement device, to act as a local oscillator.

16. A method according to claim 15 wherein the object is a partially reflecting object through which either the incident or reflected illumination passes.

17. A method according to claim 16 wherein both the incident and reflected illumination pass through the object.

18. A method according to any of claims 15-17 wherein the object is adjacent to the surface.

19. A method according to any of claims 15-18 wherein the surface is in the near field of the object.

20. A method according to any of claims 15-18 wherein the surface is outside the near field of the grating.

21. A method according to any of claims 15-20 wherein the object is a grating.

22. A method according to claim 21 wherein the grating produces essentially only a single order of transmitted illumination that illuminates the surface.

23. A method according to any of claims 15-22 wherein the illumination is at least partially coherent and wherein the object is placed within the coherence length of the illumination from the surface.

24. A method according to any of claims 15-22 wherein the local oscillator illumination and the reflected illumination are incident on at least one detector to produce said signals and wherein the local oscillator illumination and the reflected illumination are at least partly coherent at the detector.

25. Apparatus for measuring relative motion between the apparatus and a surface comprising:

an illumination source, which transmits illumination to illuminate the surface;

a first detector which receives illumination from the source, reflected from the surface;

an object which reflects a portion of the illumination to said first detector, such that the detector generates a first signal based on coherent detection of the illumination reflected from the surface with the illumination reflected by the object as a local oscillator;

a second detector which receives illumination from the source without receiving illumination reflected from the surface and generates a second signal responsive thereto;

a signal corrector that adjusts the first signal for changes in the intensity of the illumination, based on the second signal; and

a motion calculator that calculates the relative motion responsive to the signal from the signal corrector.

26. Apparatus according to claim 25 wherein the illumination from the source received by the second detector is illumination reflected from or diffracted by the object.

27. Apparatus according to claim 25 or claim 26 wherein the signal corrector corrects the first signal for a constant term based on the second signal.

28. Apparatus according to claim 27 wherein the signal corrector includes a difference amplifier that receives the first signal and subtracts the second signal from it to produce an adjusted first signal.

29. Apparatus according to claim 28 wherein the signal corrector includes a normalizer that receives the adjusted first signal and normalizes it with respect to the second signal.

30. Apparatus according to claim 28 wherein the apparatus includes:

a third detector that receives illumination reflected from the surface without receiving substantial illumination from the object or from the source and produces a third signal in response thereto, and wherein

the signal corrector corrects the adjusted signal based on the third signal.

31. Apparatus for measuring relative motion between the apparatus and a surface comprising:

an illumination source, which transmits illumination to illuminate the surface;

a first detector which receives illumination from the source, reflected from the surface;

an object which reflects a portion of the illumination to the first detector, such that the detector generates a first signal based on coherent detection of the illumination reflected from the surface with the illumination reflected by the object as a local oscillator;

a second detector which receives illumination from the source without receiving illumination reflected from the surface and generates a second signal responsive thereto;

a signal corrector that reduces the first signal by an amount proportional to the second signal; and

a motion calculator that calculates the relative motion responsive to the signal from the signal corrector.

32. Apparatus according to claim 31 wherein the illumination from the source received by the second detector is illumination reflected from or diffracted by the object.

33. Apparatus according to claim 31 or claim 32 wherein the signal corrector includes a normalizer that adjusts the first signal for changes in the intensity of the illumination, based on the second signal.

34. Apparatus according to claim 32 wherein the apparatus includes:

a third detector that receives illumination reflected from the surface without receiving substantial illumination from the object or from the source and produces a third signal in response thereto, and wherein

the signal corrector corrects the adjusted signal based on the third signal.

35. Apparatus for measuring relative motion between the apparatus and a surface comprising:

an illumination source, which transmits illumination to illuminate the surface;

a first detector which receives illumination from the source, reflected from the surface;

an object which reflects a portion of the illumination to said first detector, such that the detector generates a first signal based on coherent detection of the illumination reflected from the surface with the illumination reflected by the object as a local oscillator;

a second detector that receives illumination reflected from the surface without receiving substantial illumination from the object or from the source and produces a second signal in response thereto,

a signal corrector that reduces the first signal by an amount proportional to the second signal; and

a motion calculator that calculates the relative motion responsive to the signal from the signal corrector.

36. Apparatus according to any of claims 25-35 wherein the object is partially transmitting and wherein the object is placed between the illumination source and the surface such that illumination of the surface passes through the object.

37. Apparatus according to claim 36 wherein the illumination has a coherence length and wherein the object and the surface as situated within said coherence length.

38. Apparatus according to any of claims 25-37 wherein the object is a grating.

39. Apparatus according to claim 38 wherein the grating produces essentially only a single order of transmitted illumination that illuminates the surface.

40. Apparatus according to claim 38 wherein the surface is within the near field of the grating.

41. Apparatus according to claim 38 wherein the surface is outside the near field of the grating.

42. Apparatus according to any of claims 25-41 wherein the illumination reflected from the surface and the illumination reflected by the object are at least partly coherent at the first detector.

43. A method for determining the relative motion of a surface with respect to a measurement device, comprising:

illuminating the surface with incident illumination such that the illumination is reflected from portions of the surface;

coherently detecting the illumination reflected from the surface utilizing illumination derived from said incident illumination that was not reflected by the surface as a local oscillator, to form at least two signals;

determining the magnitude of relative motion of the surface from at least one of the two signals;

varying the phase of at least part of the local oscillator illumination with respect to at least part of the illumination reflected by the surface; and

determining the direction of relative motion parallel to the surface based on a characteristic of the signals caused by said varied relative phase.

44. A method according to claim 43 wherein the local oscillator illumination is generated by reflection or refraction of incident illumination from an object that is a part of the measurement device.

45. A method according to claim 44 wherein the object is adjacent to the surface.

46. A method according to claim 44 or 45 wherein the illumination has a coherence length and wherein the object and the surface are situated within said coherence length.

47. A method according to any of claims 44-46 wherein the object is a grating.

48. A method according to claim 47 wherein the grating produces essentially only a single order of transmitted illumination that illuminates the surface.

49. A method according to claim 47 wherein the surface is placed within the near field of the grating.

50. A method according to claim 47 wherein the surface is placed outside the near field of the grating.

51. A method according to any of claims 43-50 wherein varying the phase comprises introducing a static phase change and wherein determining the direction of relative motion comprises determining the direction of relative motion based on a characteristic of the signal caused by said static phase change.

52. A method according to any of claims 43-51 and including:

dividing the illumination that is reflected from the surface into a first illumination having a first phase and a second illumination having a second phase.

53. A method according to claim 52 wherein the first illumination and the second illumination have different polarizations.

54. A method according to claim 52 or claim 53 wherein dividing comprises passing the illumination incident on the surface through a birefringent material.

55. A method according to any of claims 52-54 wherein dividing comprises passing the illumination reflected from the surface through a birefringent material.

56. A method according to any of claims 44-51 and including placing a birefringent material between the object and the surface.

57. A method according to claim 56 wherein placing the birefringent material between the object and the surface is operative to cause detected illumination to pass through the birefringent material twice.

58. A method according to any of claims 43-57 and including determining the magnitude and direction of the translation utilizing two detectors which produce different detected signals depending on the direction of the translation.

59. A method according to claim 58 wherein determining the direction of translation comprises determining the direction from the sign of the phase difference between the different detected signals.

60. A method according to any of claims 43-59 and including linearly polarizing illumination reflected from the surface.

61. A method according to any of claims 43-60 wherein determining the magnitude of the relative motion comprises counting the zero crossings of the signal.

62. Apparatus for determining translation of a surface relative to the apparatus, comprising:

an optical block;

a detector, which produces a signal responsive to light impinging thereon, attached to the optical block; and

a source of illumination that produces illumination, a portion of which passes through the block is reflected by the surface and impinges on the detector after passing through the optical block; and

circuitry that computes the magnitude of the translation parallel to the surface, responsive to the signal.

63. Apparatus according to claim 62 and including an object within or on the surface of the block which reflects or diffracts a part of the illumination to the detector without said part impinging the surface, said part acting as a local oscillator for synchronous detection of the reflected illumination by the detector.

64. A method for determining the relative motion of a surface with respect to a measurement device, comprising:

illuminating the surface with incident radiation such that the illumination is reflected from a portion of the surface;

detecting at least a first part of the illumination reflected from the surface to form a first detected signal;

detecting at least a second part of the illumination reflected from the surface to form a second detected signal; and

determining the amount of relative motion based on a Doppler shift of the reflected radiation, wherein the first and second signals are in phase quadrature and the detection comprises quadrature detection.

65. A method according to claim 64 and including:

detecting the direction of relative motion responsive to said first and second signals.

66. A method according to claim 64 or claim 65 and including determining the relative motion in two non-colinear directions parallel to the surface.

67. A method according to any of claims 64-66 and including determining the relative motion in a direction perpendicular to the surface.

68. A method according to any of claims 64-67 wherein determining the relative motion comprises counting zero crossings of at least one of said first and second signals.

69. A method according to any of claims 64-68 wherein detecting comprises coherent detection.

70. A method for determining the relative motion of a surface with respect to a measurement device, comprising:

illuminating the surface with incident illumination such that the illumination is reflected from portions of the surface;

coherently detecting the illumination reflected from the surface using a detector, to form a signal;

utilizing illumination derived from said incident illumination that was not reflected by the surface as a local oscillator, for said coherent detection; and

determining the magnitude of relative motion of the surface from the signal;

characterized in that the local oscillator is focused onto a small area of the detector, such that essentially only a single spatial frequency of the reflected illumination forms an interference field with said local oscillator on the detector.

71. Apparatus for determining the relative motion of a surface with respect to the apparatus, comprising:

a housing having an aperture formed therein;

a detector within the housing that produces a signal utilized to determine the relative motion;

a source of laser illumination of a given wavelength, within the housing, that illuminates the surface through the aperture, such that illumination is reflected from the surface via the aperture to the detector; and

a filter covering the aperture that passes the given wavelength while blocking light at other wavelengths to which the detector is sensitive.

72. Apparatus for determining the relative motion of a surface with respect to the apparatus, comprising:

a housing having an aperture formed therein;

a detector within the housing that produces a signal utilized to determine the relative motion;

a source of laser illumination of a given wavelength, within the housing, that illuminates the surface through the aperture, such that illumination is reflected from the surface via the aperture to the detector;

a second detector within the housing that receives illumination reflected from the surface; and

circuitry that turns off the illumination source when illumination received by the second detector falls below a threshold.

73. Apparatus according to claim 72 wherein the circuitry is operative to periodically turn on the source and to turn it off if illumination received by the second detector is below the threshold.

74. Apparatus according to claim 72 or claim 73 wherein the aperture is covered by a filter that passes the given wavelength while blocking light at other wavelengths to which the first and second detectors is sensitive.

75. Apparatus according to any of claims 70-74 wherein a part of the illumination to the detector illuminates the detector, without said part first impinging the surface, said part acting as a local oscillator for coherent detection of the reflected illumination by the detector.

76. Apparatus according to any of claims 70-75 wherein the reflected illumination is Doppler shifted, by said translation, with respect to the illumination produced by the source and wherein said Doppler shift is utilized in determining the motion.

77. Apparatus for measuring relative motion between the apparatus and a surface comprising:

an illumination source, which is used to illuminate the surface;

a detector which receives illumination from the source, reflected from the surface and which receives a portion of the illumination without said portion being reflected by the surface, such that the detector generates a signal based on coherent detection of the illumination reflected from the surface with the portion of the illumination as a local oscillator, wherein said signal has a frequency related to a rate of relative movement; and

a motion calculator that calculates the amount of relative motion responsive to a count of zero crossings of the signal.

78. Apparatus according to claim 76 wherein the detector includes and including a high pass filter that filters the detector output to form said signal.

79. Apparatus according to claim 78 wherein the high pass filter has a slope of less than about 20 dB/octave.

80. Apparatus according to claim 78 or claim 79 wherein the high pass filter has a break point at a frequency corresponding to a rate of movement of less than about 0.5 mm/sec.

81. Apparatus according to any of claims 77-80 and including:

a second detector that detects at least a second part of the illumination reflected from the surface to form a second detected signal utilizing coherent detection,

wherein the motion detector determines the amount of relative motion based on a Doppler shift of the reflected radiation, wherein the signal and second detected signal are in phase quadrature and the detection comprises quadrature detection.

82. Apparatus for determining the relative motion of a surface with respect to the apparatus, comprising:

a housing having an aperture formed therein;

a detector within the housing that produces a signal utilized in determining the relative motion is determined;

a source of laser illumination of a given wavelength, within the housing, that illuminates the surface through the aperture, such that illumination is reflected from the surface via the aperture to the detector; and

circuitry that turns off the illumination source when illumination received by the detector from the surface is below a threshold.

83. Apparatus according to claim 82 wherein the circuitry is operative to periodically turn on the source and to turn it off if illumination received by the detector from the surface.

84. A method for determining the relative motion of a surface with respect to a measurement device, comprising:

placing a partially transmitting object as part of the measuring device, adjacent to the surface;

illuminating the surface with incident illumination such that the illumination is reflected from portions of the surface, wherein at least part of at least one of the incident and reflected illumination passes through the object;

detecting the illumination reflected from the surface, to generate a detected signal, wherein the object and the surface are situated within a distance that is less than the coherence length of the detected illumination; and

determining the relative motion of the surface parallel to the surface, from the detected signal.

85. A method according to claim 84 wherein the transmission of the object is spatially varying.

86. A method according to claim 84 or claim 85 wherein the object is partially reflecting and wherein part of the incident illumination is reflected or diffracted by the object, as a reference illumination and wherein detection of the illumination is coherent, utilizing said reference illumination.

87. A method for determining the relative motion of a surface with respect to a measurement device comprising:

placing a partially reflecting object, which is part of the measuring device, adjacent to the surface;

illuminating the object with incident illumination such that part of the incident illumination is reflected or diffracted by the object, as a reference illumination and part is reflected from the surface;

coherently detecting the illumination reflected from the surface utilizing the reference illumination, to generate a detected signal; and

determining the relative motion of the surface parallel to the surface, from the detected signal.

88. A method according to claim 87 wherein the object is a partially transmitting object and wherein at least part of at least one of the incident and reflected illumination passes through the object.

89. A method according to claim 87 or claim 88 wherein the reflection of the object is spatially varying.

90. A method according to claim 85 or claim 89 wherein spatially varying comprises periodic spatial variation.

91. A method according to any of claims 84-90 wherein placing an object adjacent to the surface comprises:

placing a grating adjacent to the surface.

92. A method according to claim 91 wherein placing a grating adjacent to the surface comprises:

placing the grating sufficiently close to the surface such that the surface is in the near field of the grating.

93. A method according to claim 91 wherein placing a grating adjacent to the surface comprises:

placing the grating sufficiently far from the surface such that the surface is outside the near field of the grating.

94. A method according to any of claims 84-93 wherein the detected illumination is at least partly coherent.

95. A method for determining the relative motion of a surface with respect to a measurement device comprising:

placing a grating, which is part of the measuring device, adjacent to the surface;

illuminating the grating with incident illumination such that at least part of the illumination is incident on and reflected from the surface, wherein at least one of the incident and reflected illumination passes through the grating;

generating a signal in response to the reflected illumination; and

determining the relative motion of the surface parallel to the surface, from the detected signal,

wherein the surface is in the near field of the grating.

96. A method according to claim 95 wherein generating a signal comprises detecting the illumination reflected from the surface utilizing a reference illumination.

97. A method according to any of claims 84-96 wherein the illumination reflected from the surface is frequency shifted from that of the illumination reflected from or diffracted by the object and wherein determining the motion comprises determining the motion based on the frequency shift.

98. A method according to any of claims 84-97 wherein the object has a transmission characteristic that is spatially non-symmetric.

99. A method according to claim 98 and including:

determining the direction of the relative motion based on a characteristic of the signal caused by said non-symmetry.

100. A method for determining the relative motion of a surface with respect to a measurement device comprising:

placing a partially transmitting object, which is part of the measuring device, adjacent to the surface;

illuminating the surface with incident illumination, which does not constitute an interference pattern, such that the illumination is reflected from portions of the surface, wherein at least part of at least one of the incident and reflected illumination passes through the object;

detecting the illumination reflected from the surface, and generating a detected signal; and

determining the relative motion of the surface parallel to the surface, from the detected signal.

101. A method according to any of claims 84-100 and comprising:

varying the phase between illumination reflected from or diffracted by the object and at least a portion of the illumination reflected from the surface.

102. A method according to claim 101 wherein the direction is determined based on said varied phase.

103. A method according to any of claims 84-102 and including determining motion in a direction perpendicular to the surface.

104. A method for determining the relative motion of a surface with respect to a measurement device comprising:

illuminating the surface with incident illumination such that illumination is reflected from portions of the surface;

placing a partially reflecting object, which is part of the measuring device, adjacent to the surface, wherein part of the incident illumination is reflected or diffracted by the object, as a reference illumination;

coherently detecting the illumination reflected from the surface, utilizing the illumination reflected from or diffracted by the object as a local oscillator, to form a signal;

determining the relative motion of the surface from the signal;

varying the phase of at least a part of the illumination reflected from or diffracted by the object with respect to at least a part of that reflected from the surface; and

determining the direction of relative motion parallel to the surface based on a characteristic of the signal caused by said varied relative phase.

105. A method according to claim 104 wherein placing a reflector adjacent to the surface comprises:

placing a grating adjacent to the surface.

106. A method according to any of claims 101-105 wherein varying the phase comprises periodically varying the phase.

107. A method according to claim 106, wherein determining the direction of relative motion comprises determining the direction of relative motion based on a characteristic of the signal caused by said periodically varying relative phase.

108. A method according to any of claims 101-107 wherein varying the phase comprises:
causing the object to move periodically substantially in the direction of the motion being measured.

109. A method according to any of claims 101-108 wherein varying the phase comprises:
causing the object to move periodically substantially perpendicularly to the direction of the motion being measured.

110. A method according to any of claims 101-109 wherein varying the phase comprises:
providing a transparent material between the object and the surface; and
electrifying the material such that its optical length in the direction of the illumination varies.

111. A method according to claim 110 wherein the transparent material is a piezoelectric material.

112. A method according to any of claims 100-111 and including determining both the magnitude and direction of the translation utilizing a single detector.

113. A method according to any of claims 101-105, wherein varying the phase comprises, introducing a static phase change and wherein determining the direction of relative motion comprises determining the direction of relative motion based on a characteristic of the signal caused by said phase change.

114. A method according to any of claims 101-113 and including:
dividing at least part of the illumination that is reflected from the surface into at least a first illumination having a first phase and a second illumination having a second phase.

115. A method according to claim 114 wherein said first and second illuminations have different polarizations.

116. A method according to claim 115 wherein dividing comprises passing the illumination incident on the surface through a birefringent material.

117. A method according to claim 115 or claim 116 and including passing the illumination reflected from the surface through a birefringent material.

118. A method according to claim 116 or claim 117 and including placing the birefringent material between the object and the surface.

119. A method according to any of claims 100-111 or 113-118 and including determining the magnitude and direction of the translation utilizing two detectors which produce different detected signals depending on the direction of the translation.

120. A method according to claim 119 and including determining the direction of translation from the sign of a phase difference between the different detected signals.

121. A method for determining the relative motion of a surface with respect to a measurement device comprising:

placing an apertured reflector, which is part of the measurement device, adjacent to the surface;

illuminating the surface with incident illumination such that illumination is reflected from portions of the surface and such that illumination is reflected from or diffracted by the apertured reflector;

coherently detecting the illumination reflected from the surface utilizing the illumination reflected from or diffracted by the apertured reflector as a local oscillator to form a signal;

determining the relative motion of the surface perpendicular to and parallel to the apertured reflector from the signal.

122. A method according to claim 121 wherein:

coherently detecting comprises:

detecting amplitude or phase variations of the reflected illumination; and

detecting a frequency shift of the reflected illumination; and

determining the relative motion comprises:

measuring relative motion of the surface in a direction parallel to the apertured reflector responsive to at least one of the detected amplitude or phase variations; and

measuring relative motion of the surface in a direction perpendicular to the surface of the apertured reflector responsive to the detected frequency shift.

123. A method according to claim 122 and comprising:

periodically moving the apertured reflector surface in a direction perpendicular to its surface to add a periodic phase shift to the illumination reflected therefrom; and

utilizing said phase shift to measure the motion of the surface.

124. A method for determining the relative motion of a surface with respect to a measurement device comprising:

illuminating the surface, from a source, with incident illumination such that illumination is reflected from portions of the surface toward a detector;

spatially filtering the reflected illumination such that the phase of the detected optical illumination from a given scatterer on the surface is substantially constant or linearly related to the translation of the surface;

generating a signal by the detector responsive to the illumination incident on the detector; and

determining the relative motion of the surface from the signal.

125. A method according to claim 124 wherein illuminating comprises illuminating the surface with spatially varying illumination.

126. A method according to claim 124 or claim 125 wherein illuminating the surface comprises illuminating the surface through an apertured reflector placed adjacent to the surface which reflects or diffracts illumination to the detector.

127. A method according to claim 126 wherein generating a signal comprises coherent detection of the illumination reflected from the surface utilizing the illumination reflected or diffracted from the apertured reflector.

128. A method according to any of claims 124-127 wherein determining the relative motion comprises utilizing a Doppler shift of the reflected illumination.

129. A method according to any of claims 124-128 wherein:

the illumination of the surface is substantially collimated; and

the spatial filter filters the reflected illumination such that substantially only a single spatial frequency of the reflected illumination is detected by the detector.

130. A method according to any of claims 124-129 wherein:

illumination of the surface is substantially collimated; and

spatial filtering filters the reflected illumination such that only illumination reflected from the surface substantially in a single direction is detected by the detector.

131. A method according to any of claims 124-130, wherein spatial filtering comprises:

focusing the reflected illumination with a lens having a focal point; and

placing a pinhole at the focal point of the lens.

132. A method according to any of claims 124-130, wherein spatial filtering comprises:

focusing the reflected illumination with a lens having a focal point; and

placing a single mode optical fiber at the focal point of the lens to transfer illumination to the detector.

133. A method according to claims 124-130, wherein spatial filtering comprises:

focusing the reflected illumination with a lens; and

placing a pinhole at an image of the source.

134. A method according to claims 124-130, wherein spatial filtering comprises:

focusing the reflected illumination with a lens; and

placing a single mode optical fiber at an image of the source to transfer illumination to the detector.

135. A method for determining the relative motion of a surface with respect to a measurement device comprising:

placing an object, having at least a quasi-continuous transmission function, adjacent to the surface;

illuminating the surface with incident illumination such that illumination is reflected from portions of the surface toward a detector;

detecting the illumination reflected from the surface utilizing the detector to generate a signal; and

determining the relative motion of the surface from the signal.

136. A method according to claim 135 wherein the object has an asymmetric transmission function; and

wherein determining the relative motion comprises determining the direction of motion based on the detected signal.

137. A method according to claim 135 or claim 136 wherein:

illumination is reflected from or diffracted by the object toward the detector; and

said detection is coherent detection utilizing the illumination reflected from or diffracted by the object as a local oscillator to form a signal.

138. A method for determining the relative motion of a surface with respect to a measurement device comprising:

illuminating the surface with illumination, through an apertured reflector, such that illumination is reflected from the surface to illuminate a detector with illumination which is not an image of a point on or a portion of the surface;

simultaneously illuminating the detector with reference illumination derived from said incident illumination;

coherently detecting the reflected illumination of the detector utilizing said reference illumination such that the detector generates a signal; and

determining the relative motion of the surface parallel to the surface, based on variations of the signal caused by the relative motion.

139. A method according to claim 138 wherein the incident illumination is at a given wavelength and wherein the reference illumination is at the same wavelength such that the coherent detection is homodyne detection.

140. A method according to claim 138 or claim 139 and comprising:

spatially varying the illumination of the surface.

141. A method according to claim 140 wherein spatially varying the illumination of the surface comprises:

illuminating the surface through a transmission grating having spatially varying periodic transmission.

142. A method according to claim 140 wherein spatially varying the illumination of the surface comprises:

illuminating the surface through a grating which specularly reflects a portion of the illumination incident upon it toward the detector to form said reference illumination.

143. A method for determining the relative motion of a surface with respect to a measurement device comprising:

illuminating the surface with illumination such that illumination is reflected from portions of the surface;

placing an apertured reflector adjacent to the surface;

coherently detecting the illumination reflected from the surface, utilizing illumination reflected from or diffracted by the apertured reflector as a local oscillator; and

determining the relative motion of the surface, in a direction parallel to the surface, from a characteristic of the signal.

144. A method according to claim 143 wherein the relative motion is detected utilizing a Doppler shift of the illumination reflected from the surface.

145. A method according to claim 143 or claim 144 wherein the apertured reflector is a grating and wherein illumination diffracted by the grating is used in determining the motion.

146. A method according any of the claims 84-145 wherein the illumination is perpendicularly incident on the surface.

147. Apparatus for determining the relative motion of a surface and the apparatus, comprising:

a partially transmitting object situated adjacent to the surface;

a detector that detects illumination incident on it and generates a detected signal;

a source of illumination which illuminates the object with incident illumination such that illumination is reflected or diffracted towards the detector from the object and such that part of the incident illumination is reflected from of the surface towards the detector, such that the detector coherently detects the illumination reflected from the surface utilizing the illumination reflected or diffracted towards the detector from the object; and

circuitry which determines relative motion of the surface parallel to the surface with respect to the apparatus from the detected signal.

148. A method for determining the relative motion of a surface with respect to a measurement device comprising:

illuminating the surface with illumination such that illumination is reflected from portions of the surface;

placing a partially reflecting object adjacent to the surface;

coherently detecting the illumination reflected from the surface, utilizing illumination reflected from or diffracted by the partially reflecting object as a local oscillator; and

determining the relative motion of the surface, in a direction parallel to the surface, from a characteristic of the signal based on the reflection reflected from the surface.

149. A method for determining the relative motion of a surface with respect to a measurement device comprising:

illuminating the surface, from a source, with incident illumination such that illumination is reflected from portions of the surface toward a detector;

spatially filtering the reflected illumination such that the phase of the detected optical illumination from a given scatterer on the surface is substantially constant or linearly related to the translation of the surface;

generating a signal by the detector responsive to the illumination incident on the detector; and

determining the relative motion of the surface from the signal.

150. A method according to claim 149 wherein determining the relative motion of the surface comprises determining the relative motion of the surface in a direction parallel to the surface.

151. A method according to claim 149 or claim 150 wherein illuminating comprises illuminating the surface with spatially varying illumination.

152. A method according to any of claims 149-151 wherein illuminating the surface comprises illuminating the surface through a partially reflecting object placed adjacent to the surface which reflects or diffracts illumination to the detector.

153. A method according to claim 151 wherein generating a signal comprises coherent detection of the illumination reflected from the surface utilizing the illumination reflected or diffracted from the partially reflecting object.

154. A method according to any of claims 149-153 wherein determining the relative motion comprises utilizing a Doppler shift of the reflected illumination.

155. A method according to any of claims 149-154 wherein:

the illumination of the surface is substantially collimated; and

spatially filtering filters the reflected illumination such that substantially only a single spatial frequency of the reflected illumination is detected by the detector.

156. A method according to any of claims 149-155 wherein:

illumination of the surface is substantially collimated; and

spatially filtering filters the reflected illumination such that only illumination reflected from the surface substantially in a single direction is detected by the detector.

157. A method according to any of claims 1-24, 70, 84-98, 102-105, 123-137 or 140-156 and including determining the direction of motion.

158. A method for determining the direction of relative motion of a surface with respect to a measurement device comprising:

illuminating the surface with incident radiation such that radiation is reflected from portions of the surface toward a detector;

placing an object, having an asymmetric transmission function, adjacent to the detector;

detecting the radiation reflected from the surface utilizing the detector to generate a signal; and

determining the direction of relative motion of the surface from the signal.

159. A method according to any of claims 1-24, 70, 84-158 wherein determining the motion comprises determining variations in the amplitude of the signal with position.

160. A method according to claim 159 wherein the motion is determined from zero crossings of the detected signal.

161. A method according to any of claims 1-24, 43-61, 70 or 84-160 wherein the surface is an optically diffusely reflecting surface.

162. A method according to any of claims 1-24, 43-61, 70 or 84-161 wherein the surface has no markings indicating position.

163. A method according to any of claims 1-24, 43-61, 70 or 84-161 wherein the illumination comprises visible illumination.

164. A method according to any of claims 1-24, 43-61, 70 or 84-161 wherein the illumination comprises infra-red illumination.

165. A method according to any of claims 1-24, 43-61; 70;, 84-152 and including detecting relative motion of the surface in two directions parallel to the surface.

166. An optical mouse comprising:

a housing having an aperture facing a surface; and

an optical motion detector which views the surface through the aperture, wherein the optical motion detector utilizes the method of any of claims 1-24, 43-61, 64-70 or 84-165 to determine the translation of the housing with respect to the surface.

167. A touch point for use as a control device, comprising:

a housing having an aperture; and

an optical detector which determines the motion of a finger which is translated across the aperture wherein the optical detector utilizes the method of any of claims 1-24, 43-61, 64-70 or 84-165 to determine the translation.

168. A pointer device comprising:

a first touch point according to claim 167 and circuitry which moves a pointer responsive thereto; and

a second touch point according to claim 167 and including circuitry which causes scrolling responsive thereto.

169. A combination mouse/touch point for use as a pointer for a computer comprising:

a housing having an aperture;

an optical detector which determines the motion of an object which is translated across the aperture; and

means for determining whether the aperture is upward or downward facing.

170. A combination mouse/touch point according to claim 169 wherein the optical detector utilizes the method of any of claims 1-24, 43-61, 64-70 or 84-165 to determine the translation.

171. A scanner for reading a document by movement of the scanner over the document comprising:

an optical reading head which detects patterns on the surface of the document; and

an optical detector which determines the motion of the scanner as it is translated across the surface of the document, wherein the optical detector utilizes the method of any of claims 1-24, 43-61, 64-70 or 84-165 to determine the translation.

172. A scanner according to claim 171 wherein the patterns comprise printed patterns.

173. A scanner according to claim 171 or claim 172 wherein the patterns are handwritten patterns.

174. A scanner according to claim 173 wherein the patterns are a signature.

175. An encoder comprising:

an optically diffusely reflecting surface having no markings other than reference markings; and

an optical detector having relative motion with respect to the surface, wherein the optical detector measures relative motion with respect to the surface relative to the reference markings, wherein the optical detector utilizes the method of any of claims 1-24, 43-61, 64-70 or 84-165

176. An encoder according to claim 175 wherein the surface is the surface of a disk which rotates about an axis and wherein the detector measures the rotation of the disk.

177. A virtual pen comprising:

an encoder according to claim 175 or claim 176; and

circuitry which translates said measured relative motion into written or graphical data.

178. A device for moving a sheet of paper comprising:

means for moving the paper; and

an optical detector which measures the movement of the paper without utilizing any markings on the paper,

wherein the optical detector utilizes the method of any of claims 1-24, 43-61, 64-70 or 84-165

179. A document scanner comprising:

a device according to claim 178;

a reading head which reads information from the paper; and

a memory which stores the information in memory locations responsive to the measurement of movement of the paper.

180. A printing machine comprising:

a device according to claim 178;

memory which contains information to be printed on the sheet of paper; and

a printing head which prints the information responsive to the measurement of movement of the paper.

181. A facsimile machine comprising a scanner according to claim 179.

182. A facsimile machine comprising a printer according to claim 180.

183. A facsimile machine according to claim 182 and further comprising a scanner according to claim 179.